THE ASSESSMENT OF VARIABILITY FOR SOME MORPHOLOGICAL AND QUALITY TRAITS OF FRUITS IN DIFFERENT CULTIVARS OF STRAWBERRY

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Abstract. *The commercial value of strawberry cultivars depends mostly on the appearance of the fruit and their quality, mainly their size and sugar content. The aims of this study were to assess the morphological and quality fruits traits of eight strawberry cultivars with different genetic and ecologic origin. The highest variation among the studied varieties was recorded for fruits shape and inner cavity size, but those characters had a lower influence on fruits weight variability. For this set of genotypes, the fruits diameter has contributed more than their length to achieve their weight. Also, the sizes of the fruits are negatively correlated with the sugar content. Cultivar Elsanta's sugar content was significantly higher than all the other varieties and was associated with elongated fruits shape of small size. The biggest fruits were observed in genotype A2, which has a flattened shape fruits with a full pulp, but characterized by lower than average sugar content. The results indicate that there is a considerable variability between the studied cultivars that can be exploited in strawberry breeding programs for quality traits.*

Key words: *strawberry, morphological, quality traits, variability.*

INTRODUCTION

The commercial value of strawberry cultivars depends mostly on the appearance of the fruit and their quality, mainly their size and sugar content. Genotype-variety is the major factor in determining fruit nutritional quality, but it is also affected by crop conditions (environmental and cultivation techniques), ripening season, pre-harvest and post-harvest conditions, shelf-life and processing [1, 2, 4, 9, 10, 14].

Among fruit species, strawberries have more total antioxidant content (from 2- to 11-fold) than have apples, peaches, pears, grapes, tomatoes, oranges or kiwifruit [12]. Besides its attractive color and taste, strawberry is also a good source of carbohydrates, vitamin C, and other antioxidant compounds, such as phenolics and flavonoids [11, 5]. In addition to flavor components, other quality attributes are influenced by stage of development and genetic and environmental factors [7]. Cultivar and maturity are the factors considered to have the greatest effect on strawberry color [13]. The degree of softening at the ripe stage of strawberries is highly dependent on cultivar and preharvest environment [6, 8].

The current study aims were to assess the morphological and quality fruits traits of eight strawberry cultivars with different genetic and ecologic origin.

MATERIAL AND METHODS

The studied biological material was represented by eight strawberry genotypes with different genetic and ecological origin: A1 (Romania); A2 (Romania), Alba (Italy), Clery (Italy), Marmolada (Italy), Mira (Canada), Onda (Italy), Elsanta (Netherlands). The genotypes in question were studied in a randomized blocks design with four replications on plots of three rows with 25 plants (75 plants per plot) grown at distances of 1m x 0.20 m. The experiment has been located in Topolavatu-Mare on an alluvial soil.

The plants in the experiment were in the second (2014) and third year of fruiting (2015). During the growing season the classic technological steps were applied (for organic farming) represented by the following measures: weed control and soil loosening by manually tilling between the plants and mechanized cultivation between rows, applying straw mulch, removal of runners during fructification,

manual weeding, foliar calcium application (prevention of mildew). The crop was not irrigated and no chemical fertilizers were applied.

In order to assess the content of sugar (by refractometer) and morphological traits (weight-Fw, length-Fl, diameter-Fd, inner cavity length-Icl, inner cavity diameter-Icd, shape index-Si) of fruits, determinations were made on 10 representative fruits per genotype and replication on the ripeness peak.

Data were statistically analyzed using analysis of variance and least significant difference test [3]. The significance of differences was expressed based on letters, being considered as significant the differences between variants marked with different letters. To make possible the display in a single graph of the performance of each genotype for each of the five traits, the basic principle of the biplot technique developed by Gabriel (1971) and GGE biplot method developed by YAN ET. AL. (2000) was used.

RESULTS AND DISCUSSIONS

Considering the results of analysis of variance (Tab. 1) there appears to be significant differences between the eight cultivars for all studied traits. The highest difference between genotypes was recorded for fruit shape and their diameter, while in terms of inner cavity diameter and fruit weight there were lower differences. The experimental conditions between replication showed a small and insignificant influence on the sugar content of the fruit, average weight and diameter or their shape. The fruit length and size of the inner cavity of the fruit were significantly influenced by the replications effect.

Table 1.

Analysis of variance for some morphological and quality traits of fruits in strawberry cultivars

Variation sources	DF	MS	F	Variation sources	DF	MS	F
Sugar content				Inner cavity length			
Replications	3	0.30	0.45	Replications	3	31.78	16.94**
Cultivars	7	5.53	8.24**	Cultivars	7	18.9	9.80**
Error	21	0.67		Error	21	1.88	
Fruit weight				Inner cavity diam.			
Replications	3	12.45	0.86	Replications	3	27.70	10.00**
Cultivars	7	107.35	7.41**	Cultivars	7	18.64	6.73**
Error	21	14.50		Error	21	2.77	
Fruit length				Fruit shape index			
Replications	3	8.50	3.80*	Replications	3	0.005	1.07
Cultivars	7	25.86	11.55**	Cultivars	7	0.073	16.99**
Error	21	2.24		Error	21	0.004	
Fruit diameter							
Replications	3	6.28	1.27				
Cultivars	7	60.01	12.13**				
Error	21	4.95					

In terms of sugar content, the studied cultivars presented values ranging from 5.88 % in Onda to 9.88 % in Elsanta, based on a low inter-genotypic variability of 2.62 %. The variety that stood out was Elsanta by accumulating a significant amount of sugar in fruit, significantly superior to other varieties. Cleary, A1 and Mira cultivars had the sugar content significantly higher than Onda variety. There were no significantly differences for sugar content between the other genotypes. The highest intra-population variability was recorded in Marmolada and A1's fruit, while the fruit of Elsanta and Clery showed a high uniformity of this trait.

Table 2

Mean values of sugar content and fruit weight in strawberry cultivars

No	Cultivar	Sugar content (%)		Fruit weight (g)	
		$\bar{x} \pm s_{\bar{x}}$	s %	$\bar{x} \pm s_{\bar{x}}$	s %

1	A1	7.75±0.63b	16.24	14.00±1.47de	21.03
2	A2	7.00±0.05bc	1.40	27.25±1.89a	13.85
3	Alba	6.75±0.48bc	14.18	16.25±0.25cde	3.08
4	Clery	7.88±0.13b	3.17	16.50±0.29cde	3.50
5	Marmolada	6.88±0.59bc	17.18	23.75±2.32ab	19.55
6	Mira	7.25±0.25b	6.90	18.25±0.63bcd	6.89
7	Onda	5.88±0.43c	14.53	21.50±0.65bc	6.00
8	Elsanta	9.88±0.13a	2.53	11.75±0.48e	8.15
	Mean	7.41±0.10	2.62	18.66±0.62	6.69
	$LSD_{5\%}$	1.20		5.60	
	$LSD_{1\%}$	1.64		7.62	
	$LSD_{0.1\%}$	2.21		10.28	

The average fruit weight showed variation amplitude of 15.50 g, with a range from 11.75 for A2 to 27,25g for Elsanta, associated with low inter-genotypic variability (6.69 %), but higher than in the sugar content. Based on multiple comparisons between cultivars, it was observed that the weight of fruit in A2 genotype was significantly higher than other varieties with more than 15 %. The Marmolada variety's fruit weight was significantly superior to the other varieties, except for Mira and Onda. The greater uniformity of fruit was found in varieties Alba and Clery while for A1 genotype and Marmolada cultivar was observed a high inter-individual variability for this character.

Table 3

Mean values of fruit length and diameter in strawberry cultivars

No	Cultivar	Fruit length (mm)		Fruit diameter (mm)	
		$\bar{x} \pm s_{\bar{x}}$	s %	$\bar{x} \pm s_{\bar{x}}$	s %
1	A1	32.50±0.96e	5.89	31.50±1.19bcd	7.56
2	A2	36.00±1.08cd	6.00	41.25±1.70a	8.25
3	Alba	38.50±0.50ab	2.60	30.75±0.85cd	5.55
4	Clery	38.00±0.91bc	4.80	31.50±0.65bcd	4.10
5	Marmolada	37.25±1.03bc	5.53	34.75±1.18b	6.80
6	Mira	40.50±0.65a	3.19	31.75±0.75bc	4.72
7	Onda	38.00±0.41bc	2.15	33.50±1.66bc	9.90
8	Elsanta	34.25±1.11de	6.47	28.25±0.25d	1.77
	Mean	36.88±0.52	2.80	32.91±0.44	2.69
	$LSD_{5\%}$	2.20		3.27	
	$LSD_{1\%}$	2.99		4.45	
	$LSD_{0.1\%}$	4.04		6.01	

Regarding the length of fruit, the studied cultivars showed a reduced amplitude variation (8 mm) between 40.50 mm in Mira and 32.50 mm in A1, associated with a very low variability (2.80%). Mira variety's fruit were significantly longer than the other varieties except for Alba, who in turn registered a fruit length significantly superior to A2, A1 and Elsanta. Generally, there is a high uniformity of the fruits length for all studied genotypes.

In terms of fruit diameter the studied cultivars presented values ranging from 28.25 mm in Elsanta to 41.25 mm in A2, due to a low inter-genotypic variability of 2.69 %. Thus, cultivar A2 stood out, registering a fruit diameter significantly superior to other varieties. The fruit diameter of Marmolada variety was significantly higher than Elsanta and Alba. The highest intra-population variability was recorded in fruit of Onda and A2, while Elsanta's fruits had a very high uniformity for this trait.

Table 4

Mean values of inner cavity length and diameter of fruits and shape index in strawberry cultivars

No	Cultivar	Inner cavity length (mm)		Inner cavity diam. (mm)		Shape index	
		$\bar{x} \pm s_{\bar{x}}$	s %	$\bar{x} \pm s_{\bar{x}}$	s %	$\bar{x} \pm s_{\bar{x}}$	s %
1	A1	17.75±1.25bc	14.08	11.00±1.47b	26.76	1.03±0.02d	4.46

2	A2	15.00±1.68d	22.44	14.00±2.04a	29.16	0.87±0.02e	4.80
3	Alba	19.75±0.75ab	7.59	9.00±0.91bc	20.29	1.26±0.04a	6.63
4	Clery	19.75±0.85ab	8.65	7.75±1.18c	30.49	1.21±0.01ab	0.95
5	Marmolada	17.00±1.73cd	20.38	8.00±1.35c	33.85	1.07±0.02cd	3.02
6	Mira	21.75±1.11a	10.19	8.25±0.63c	15.25	1.28±0.04a	5.94
7	Onda	18.25±0.95bc	10.37	9.50±0.50bc	10.53	1.14±0.06bc	10.07
8	Elsanta	16.50±0.65cd	7.82	7.75±0.85c	22.04	1.21±0.03ab	5.09
	Mean	18.22±0.99	10.24	9.41±0.93	19.78	1.13±0.02	12.42
	$LSD_{5\%}$	2.01		2.45		0.10	
	$LSD_{1\%}$	2.74		3.33		0.13	
	$LSD_{0.1\%}$	3.70		4.50		0.18	

The length of the inner cavity of the fruits showed a variation of 6.75 mm amplitude, with a range from 15 mm in Mira to 11.75mm in A2, associated with medium inter-genotypic variability (10.24 %), but superior to the traits presented above. Based on the multiple comparisons between varieties, it was found that Mira's fruits had a significantly longer inner cavity by more than 19 % than most of the cultivars. Clery and Alba recorded values significantly superior to A2, Elsanta and Marmolada. The greater uniformity of fruit for this trait was found in Alba and Elsanta while A2 genotype and Marmolada cultivar showed high variability.

Regarding the inner cavity diameter of fruits, the studied cultivars showed a less amplitude variation (6.25 mm) between 14 mm for A2 and 7.75 mm for Clery and Elsanta, associated with a high intra-population variability (19, 78 %). A2 genotype had a significantly wider inner cavity of fruits than the other varieties, followed by A1 which in turn recorded a significantly superior inner cavity diameter than Clery, Marmolada, Mira and Elsanta. Inter-individual variability was medium (for Onda and Mira) or high, considerably bigger than in the case of other studied traits.

In terms of fruit shape index, the studied cultivars presented values between 1.28 in Mira and 0.87 in A2, due to a medium inter-genotypic variability of 12.42 %. Thus, Mira and Alba's fruits were significantly longer than of Onda, Marmolada, A1 and A2. Onda recorded the highest intra-population variability for fruits shape, while Clery fruits showed a very high uniformity of this character.

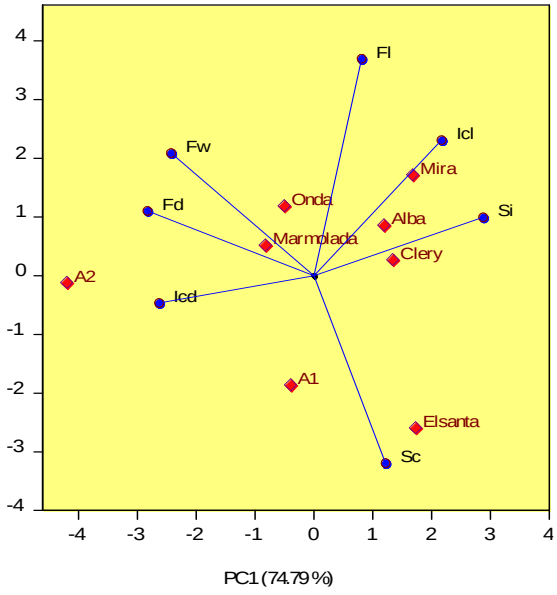

Fig. 1. Biplot for for some morphological and quality traits of fruits in strawberry cultivars

For these eight strawberry cultivars the biplot (Fig. 1) based on the first two principal components express 94.26 % of the variability of the seven characters taken in the study. Given the angles between the vectors of traits is observed that for this set of genotypes, the fruits diameter has contributed more than their length to achieve their weight. Also, the sizes of the fruits are negatively correlated with sugar content.

Depending on the projection of each genotype on the vectors of different traits, we find that Elsanta variety presented significantly higher sugar content than other varieties associated with reduced fruits size and elongated shape. The biggest fruits were observed in genotype A2, which have a flattened shape, a full pulp, but were characterized by a lower than average sugar content. Mira's oblong fruits were associated with a higher than average weight, and low sugar content. Genotype A1's regular shape of the fruits is correlated with lower then average fruits size and high sugar content.

CONCLUSIONS

1. The highest variation among the studied varieties was recorded for fruits shape and inner cavity size, but those characters had a lower influence on fruits weight variability.

2. For this set of genotypes, the fruits diameter has contributed more than their length to achieve their weight. Also, the sizes of the fruits are negatively correlated with the sugar content.

3. Cultivar Elsanta's sugar content was significantly higher than all the other varieties and was associated with elongated fruits shape of small size.

4. The biggest fruits were observed in genotype A2, which has a flattened shape fruits with a full pulp, but characterized by lower than average sugar content.

5. The results indicate that there is a considerable variability between the studied cultivars that can be exploited in strawberry breeding programs for quality traits.

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